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Bruce B. Hostetler

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DETECTION AND EVALUATION PROCEDURES FOR POTENTIAL DOUGLAS-FIR TUSSOCK MOTH OUTBREAKS

USDA Forest Service
P. O. Box 3623
Portland, Oregon 97208

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Detection and Evaluation Procedures for Potential Douglas-fir Tussock Moth Outbreaks

(An action plan implementing technology derived from the Douglas-fir Tussock Moth Research and Development Program)

BY

Tom Gregg and D. B. Twardus

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INTRODUCTION

One important generalization to be made about Douglas-fir tussock moth (DFTM) outbreaks is that the population builds up rapidly (Mason 1974). In 3 years, a DFTM population can go from very low numbers to outbreak proportions where top-killing and tree mortality occur (Wickman et al 1973).

From a survey standpoint, early detection of an increasing population is critical to making a treatment recommendation before tree damage occurs. In Figure I, a systematic approach to early detection and evaluation is presented. The figure illustrates how techniques developed during the Douglas-fir tussock moth Research Program can be used to put the resource manager in a position to make a treatment decision with maximum information gained in a minimum amount of time. The timing and organization of these techniques is important. We have arranged the techniques in a series of levels, each of which provides information needed to enter the next level. The figure is read from bottom to top; this illustrates that a treatment recommendation is built upon a series of decisions. The resource manager makes the ultimate treatment decision, but the levels shown in Figure 1 dictate the time and place that decision is made, and the effectiveness of that decision.

Parts of this process have been described in the publication "Douglas-fir Tussock Moth: A Synthesis" (Brookes, Start, and Campbell, eds; 1978).

Figure 1. A detection and evaluation action plan leading to a tussock moth treatment recommendation.

The tussock moth treatment recommendations
Level VIII
Check outbreak boundries with pheromone traps; conduct egg viability surveys.
Level VII
Make the decision to initiate or not the NEPA process.
Level VI
Use population densities and stand data to run the model.
Level V
Obtain stand inventory data to localize the model
Level IV
Collect density estimates through mid-crown branch sampling.
Return to pheromone trapping.
Low-level classification indicates no immediate problem.
Sub-outbreak
Sub-outbreak classification. Population may be 1 year from outbreak status.
Level III
Use lower-crown sequential larval survey to classify population increase.
25 or more
Level II
Use pheromone traps to monitor population. Average trap catch of 25 or more is a red flag.
Establish detection priorities.
Level I
Conduct stand risk-rating.
Evaluate resource management objectives.

Summary of Detection and Evaluation Procedures
Shown in Figure 1

Level I - Within the susceptible host type areas, identify those areas where DFTM damage would potentially impact resource management objectives. These areas should be risk-rated for vulnerability to DFTM damage (see Agric. Handbook No. 569). Risk-rating should include use of the combined tussock moth stand-outbreak model to simulate the likely consequences of an outbreak.

Level II - Pheromone trap placement and monitoring within susceptible areas. Average trap catch of 25 or more indicates population buildup.

Level III - At this level, the survey entomologist needs only to determine if the population is a potential problem; accurate density estimates are not required unless the population appears to be in a sub-outbreak phase. Sequential larval surveys are used in Level III to classify the population as low-level or sub-outbreak.

Level IV - If Level III survey indicates sub-outbreak population density estimates are obtained in Level IV sampling. These are mid-crown branch samples.

Level V - "Localize" the DFTM stand-outbreak model for the specific stand conditions involved; this includes making biomass estimates, as well as collecting some stand inventory data.

Level VI - Use the pest population and stand data to run the combined stand-outbreak model. Output from the model will assist in formulating treatment recommendations.

Level VII At this point, the decision to initiate the NEPA process must be made.

Level VIII - If treatment is a possibility, outbreak boundaries should be determined by extensive pheromone trapping. Population quality should be assessed through egg mass viability and virus incidence sampling.

Level I, Establishing Priorities

Survey or monitoring of DFTM populations must be tied directly to resource management objectives. Different management objectives result in different damage thresholds, and, hence, require different survey intensities. For example, management objectives of a National Park may necessitate minimum early warning monitoring while the commercial forest land of a National Forest may need intensive monitoring.

As shown in Figure 1, the decision process starts with deciding where DFTM populations will be monitored. These areas should be risk-rated using techniques described by Stoszek et al (1977), Heller et al (1977), and specifically in Agriculture Handbook No. 569 by Heller et al (1980). These studies conducted to develop risk-rating systems indicate that certain site and stand characteristics influence DFTM outbreaks. Combining the biological and socio-economic susceptibility of areas allows resource managers to reduce the overall size of the host type requiring monitoring. This is important as the cost of pest survey escalates with increasing size of area. Routine surveys can account for sizable budgetary impacts in themselves, hence, higher priority must be given to areas where resource management can be impacted by defoliation.

Some population monitoring will undoubtedly begin before risk-rating is complete. But the resource manager working with the survey entomologist should, at least, delineate areas where pest damage concerns are obvious.

It is also useful at this point for the resource manager to develop an idea of when damage is unacceptable. For example, some areas can tolerate top-kill and tree mortality without affecting the resource management objectives. In these areas, intensive survey and early warning of DFTM population increase is not necessary. The DFTM stand-outbreak model is also available to simulate an outbreak in typical stand conditions for a given area. This information can be used to determine more precisely the consequences of not detecting and treating an outbreak early.

In summary, the first step in a DFTM detection and evaluation strategy is knowing in what types of stands to start. The goal is to establish detection priorities based upon resource values and biological susceptibility of the areas. This is the first step in managing the pest, and not letting it manage you.

Level II, Monitoring Low-Level Populations (Early Warning)

Mason (1974), working in central Arizona, measured a DFTM population increase rate of about 7-fold between generations. Similar results were obtained from Region 6 tree beating plots located on 7 Ranger Districts on the Wallowa-Whitman and Umatilla National Forests (Table 1). As shown in Table 1, DFTM larvae were first collected from the monitoring plots in 1970. In 1971, there was an average 5-fold increase in number of larvae collected and in 1972 larvae numbers showed an average 9-fold increase.

The defoliator monitoring plots provided early warning of the DFTM outbreak. These plots consisted of three host trees (15-20 feet in height). One side of each tree in the plot was beat with a long pole, thereby dislodging larvae to

a sheet spread below. There were eight plots on each East Side Ranger District throughout the range of Douglas-fir and true fir in Oregon and Washington. Larvae counts one year to the next provided the indication of population increases. Due to the small sample size at any given point, and to the possible rapid population increase, the presence of one DFTM larva at any plot served as a warning of possible population buildup.

The defoliator "beating" plot may not be the best way to monitor low-level DFTM populations. Daterman et al (1979) in Agriculture Handbook No. 546 describe the use of pheromone-baited sticky traps as a low-level population monitoring tool. Pheromone traps sample male adult moths; the most mobile stage in the DFTM life cycle. At low population levels, this represents a distinct advantage, over larval or egg mass sampling. Average per plot trap catches of 25 or more male moths are considered indicative of an increasing population (Daterman et al, 1979).

In the Pacific Northwest Region, pheromone trapping will be used as the principal early detection survey system (Level II). Each plot will have 5 traps, with numbers of plots per area dependent upon priorities established in Level I. An average trap catch of 25 or more male moths per trap will be used as an indication that additional population sampling (Level III) is required.

The entomologist may choose to "ground check" pheromone plot results. Areas where high numbers of male moths are trapped, especially if they are high hazard areas, can be checked for signs of defoliation. Visible defoliation is not expected at this time, and if observed, indicates early warning has failed and plans should immediately be made to evaluate the potential outbreak. If justified, population density can be estimated with an egg mass survey (i.e., proceed to Level IV, obtain density estimates).

Pheromone traps for DFTM detection will be used on an annually recurring basis in areas designated in Level I. Any time moth counts average 25 or more per plot, Level III sampling will take place the following spring. This system will provide acceptable "lead time" to assess the potential outbreak and make treatment recommendations.

TABLE 1.--The original tree-beating plots on Umatilla and Wallowa-Whitman National Forests (1966-1974).

RANGER DISTRICT	PLOT NO.3/	1966-1969	1970	1971	1972	1973	1974
Pomeroy	1	0	1	0	83	57	0
Pomeroy	2	0	0	0	11	200+	0
Walla Walla	3	0	1	3	63	160	0
Bear-Sleds	4	0	1	8	62	200+	103
Bear-Sleds	5	0	4	15	162	200+	0
Chesnimnus	6	0	1	0	3	6	3
Joseph	7	0	0	0	0	0	2
Bear-Sleds	8	0	0	0	0	0	0
Walla Walla	9	0	1	0	4	5	0
Pendleton	10	0	9	53	75	200+	26
La Grande	11	0	0	0	0	0	0
Baker	12	0	0	0	0	0	0
Baker	13	0	0	0	0	0	0
Pine	14	0	0	0	1	4	0
Pine	15	0	0	1	4	25	0
Baker	16	0	0	0	1	1	0
Unity	17	0	0	0	0	0	0
Ukiah	31	1/	0	0	0	0	0
Ukiah	32	1/	0	0	0	0	0
Chesnimnus	33	2/	0	0	0	0	3
Total		0	18	80	469	1058+	137
Mean		0	.9	4.0	23.5	52.9+	6.9

1/ Plots not sampled in 1969.
2/ Plot established in 1970.
3/ Plot Numbers 7, 8, 11, 12, 13, 17, 31, and 32 were outside the general outbreak area.

Level III, Classify Population Level

In Level III, we begin quantifying the population, still without spending too much time or money. The pheromone traps have given us the cheapest way to monitor low populations, and as such we're not too concerned about how precisely they work. In Level III, which occurs the following spring, we can more reliably find where a population buildup is occurring.

In this level, we use sequential larval survey procedures developed by Mason (1978). These procedures use lower branch beating to classify plots as either low-level or suboutbreak. The classification is based upon population dynamics. Tree defoliation is not visible until larvae average 20 per 1,000 square inches of branch foliage. This is just a handy generalization used to define the word outbreak. And, as discussed earlier, an annual multiplication rate of 7 is used to describe how a population can increase one year to the next. So if a population averages 1 larvae/1,000 square inches of foliage, it would take at least 2 years for it to increase to visible defoliating levels (i.e., 1x7 = 7 larvae per 1,000 square inches by the next year, so it would take another year for it to exceed 20 larvae per 1,000 square inches). Anything around 1 larvae per 1,000 square inches is considered low-level.

On the other hand, a population of 3 larvae per 1,000 square inches of foliage is considered to be only 1 year away from outbreak conditions, so we call this sub-outbreak. An intermediate classification is anything between 3 larvae per 1,000 square inches and 1 larvae per 1,000 square inches of foliage.

Mason (1978) has done all the calculations necessary to transform information about the population dynamics into a sequential survey tool for rapid classification of plots as low-level or sub-outbreak. The survey is based upon whether or not DFTM larvae are present on sampled branches--no larvae counting is necessary. The number of trees required to sample a particular place can range up to about 20 depending upon population levels. Mason's paper on detecting suboutbreak populations of the Douglas-fir tussock moth by sequential sampling of early larvae in the lower tree crown (1978) is an excellent description of the sampling plan.

The pheromone trapping in Level II represents an "in place" early warning of population increase. Sequential larval surveys are used to follow-up any indication of increase. The larval survey is done not just at the pheromone plot showing an increase but all around the general area of the plot. Distributing the sequential larval plots allows the entomologist to estimate the geographic extent of any DFTM population increase.

Level IV, Obtain Density Estimates

Where the sequential survey shows sub-outbreak or intermediate populations, larval density should be estimated by mid-crown branch sampling as described by Mason (1970). This method is best suited for high population levels, where accurate density estimates are required. The sequential survey of Level III will broadly outline where to focus the intensive sampling efforts. Areas classified as sub-outbreak or intermediate are delineated for possible direct control consideration, while low-level areas are set aside for further monitoring. Within areas described as sub-outbreak mid-crown branch sample plots

are established. Mid-crown branch samples are used to determine numbers of early instar larvae per 1,000 sq. in. of foliage. Mason (1970) reports that at outbreak levels (20 larvae per 1,000 sq. in. of foliage), it requires 12 sample trees to estimate population density with a 20 percent accuracy level. This, however, is for a single sample unit approximately 1 acre in size. Since our larval density information is needed for much larger areas, sample design must incorporate population variation over large areas.

Table 2 shows an example of the number of tree clusters required to provide different levels of precision for various number of trees per plot. Data used for this analysis were obtained from a 1973 DFTM operational insecticide test in eastern Oregon (Anonymous 1974, unpubl.). The table shows how plot size is dependent upon required precision. To estimate mean larval density $\pm$ 20%, 40 plots can be used each having 1 tree per plot. This, of course, is also dependent upon the size of the area involved. These data were developed from an area about 5,000 acres in size.

TABLE 2.--Number of clusters required to provide different levels of precision for various numbers of trees per plot in a two-stage sample of early instar Douglas-fir tussock moth larvae.[1/]

Number of sample trees per plot	Standard error as percent of mean				
	5	10	15	20	40
	- - - - - - - - - - Number of plots - - - - - - - - - -				
1	615	155	70	40	10
2	500	125	55	32	8
3	465	115	52	30	7
4	445	112	50	28	7
5	435	110	48	27	7
7	420	105	47	26	7
10	410	103	46	26	6
15	400	100	45	25	6
20	400	100	45	25	6

1/ These data are based on DFTM data collected during the 1973 operational insecticide test in eastern Oregon, Washington, and Idaho. $\bar{x}$ = 167.6; n = 36; N = 99999; m = 10; M = 250; estimated population variance among clusters = 27335.1, among trees = 16703.2.

If cost of sampling is included, sample size is changed. Table 3, line 5, shows, for example, that if it cost $20 to get to a plot, and say $2 (column 2) to sample a tree, then the optimum sample for a large area is 32 plots each containing 2 trees (20% standard error).

TABLE 3.--Effects of cost on estimating optimum sample size in a two-stage Douglas-fir tussock moth survey - plots(n) and trees(m)[1/]

First Stage[2/] Cost (1)	Second Stage[3/] Cost (2)	Ratio $C_{(1)}/C_{(2)}$	15% SE (n)	15% SE (m)	20% SE (n)	20% SE (m)
$20.00	$20.00	1.00	70	1	40	1
20.00	10.00	.50	70	1	40	1
20.00	5.00	.75	57	2	32	2
20.00	3.00	.15	57	2	32	2
20.00	2.00	.10	57	2	32	2
20.00	1.00	.05	50	4	28	4
20.00	0.80	.04	50	4	28	4
20.00	0.50	.03	49	5	27	5
20.00	0.30	.02	47	7	27	7
20.00	0.10	.005	46	11	26	11

1/ (n) = optimum sample size at first stage (clusters).
(m) = optimum sample size at second stage (trees).

2/ First stage cost = average cost associated with first stage samples; i.e., cluster - cost does not include within cluster cost.

3/ Second stage cost is the cost required to sample an average tree including measuring foliage, counting insects, and recording data.

These data are presented to illustrate that mid-crown branch sampling for density estimates is a major undertaking. Both the resource manager and the survey entomologist should be sure that this level of sampling is appropriate before data are collected.

The sequential larval survey tells which areas are sub-outbreak. This is a relatively rapid and inexpensive way of locating an increasing population. Midcrown branch sample surveys follow-up the sub-outbreak classification by estimating larval densities. These density estimates will be used in the DFTM stand outbreak model to project potential resource losses.

Density estimates are expensive and time-consuming. The purpose in doing sequential larval surveys before mid-crown branch samples is to concentrate the expensive sampling on areas really needing it.

Based upon costs and characteristics of the area, the entomologist can choose an appropriate sample allocation. One possibility is; field crews can be directed to establish mid-crown sample plots at every other sequential plot classified as intermediate or sub-outbreak. As a "picture" of the potential outbreak develops through data collection, the entomologist can direct field crews to areas needing additional population density estimation. The sequential survey helps outline <u>where</u> the problem is, and the density plots <u>quantify</u>

it. It is important that the potential outbreak be outlined by larval rather than egg mass sampling. As Mason (1970) points out, the clumped distribution of egg masses, especially at lower population densities, require very large numbers of sample trees to achieve any reasonable amount of precision. At a 20 percent precision level, for example, it requires five times more trees to estimate DFTM egg mass population density, on 1 acre, than it does larval populations (Mason, 1970).

The emphasis of Levels III and IV is to focus delineation of the potential outbreak upon larval sampling. Egg mass sampling should occur only in emergency situations where early warning has failed to detect an increasing population.

Level V, Obtain Stand Condition Information

If, during the larval sampling process, mid-crown larval densities are estimated at 3.0 or more per 1,000 sq. in. of foliage, defoliation estimates should be made from a subsample of the larval plots. This activity begins when larval feeding ceases, and is intended to contribute to the overall evaluation of outbreak significance. As shown in Figure 1, information collected at this time will be used in running the DFTM outbreak model.

At this stage of the outbreak, significant defoliation is not expected. But data estimating the amount of defoliation that has occurred, together with population projections, contribute to the evaluation. Visual defoliation estimates are made by recording damage in one of seven defoliation classes based upon percent of crowns defoliated (Wickman 1979). The sampling allocation used for the larval density plots (plots and trees of Level IV) can also be used for the defoliation estimates.

Forest stand and site information should also be collected at this time. Data such as tree species, habitat type, diameters, and past damage are required to calibrate the stand prognosis part of the outbreak model. In addition, measurements of crown ratios, tree height, periodic increment, and stand age are used to localize stand projections. This information can be gained from existing up-to-date timber inventory records of the affected area or obtained by conducting specific stand sampling surveys (see Stage and Alley 1972). In all likelihood, sufficient time to conduct a specific stand inventory will not exist - so as accurate in-house information as possible should be used.

The better the stand inventory data collected, the more realistic will be the stand prognosis projections. Variables which must be localized for the particular tussock moth population are insect density, biomass of the new foliage and either percentage new foliage or biomass of the old foliage; the foliage information is needed for each of the host species considered.

Level VI, Run the Model

The DFTM combined stand outbreak model integrates DFTM population information with projections of tree damage. As stated by Campbell and McFadden (1978), the model was not constructed to make decisions, but to be used as a tool in the decisionmaking process. The model does not predict outbreaks; it assumes an outbreak is imminent. As a consequence, it is extremely important to know

what the insect is doing. And that is why the timing and organization of this evaluation process is so important. The information collected provides confidence to a decision of whether or not an outbreak is imminent.

As previously discussed, the resource manager and the survey entomologist should use the combined model in advance of detection (Level I). A number of "what if" runs using local stand conditions will reveal potential damages and serve to justify an appropriate expenditure for surveys and sampling.

At Level VI, the model is being calibrated for specific stand conditions, and the output will be used for the Environmental Analysis.

The NEPA Decision, Level VII

As shown in Figure 1, the decision to begin the NEPA process analyzing the need for treatment should come as the result of information gained throughout the evaluation process. It follows review of DFTM model scenarios and site-specific management objectives of the affected area. We use the NEPA decision here as the final level because once this decision is made, another entirely new process starts--that outlined by the National Environmental Protection Act.

The decision to do an Environmental Analysis of treatment alternatives requires considerable commitment on the part of the resource manager and pest management specialists, so we want the decision to start preparing this document to be based upon adequate and reliable information. The evaluation process is arranged so the NEPA decision can be made early in the outbreak cycle and yet be based upon maximum information. Hypothetically, the decision to begin the NEPA process can be made as early as late summer, 1 year after initial detection of an increasing population. This strategy would allow an early treatment before tree damage occurs. It is based partly upon the assumption that a DFTM outbreak will have 3 phases similar to prior outbreaks; a release phase, a peak phase, and a decline phase, and the whole outbreak can be over in 4 years (Wickman et al 1973).

The decision to begin the NEPA process should occur at about the same time as Level VIII activities (check outbreak boundaries by extensive pheromone trapping, and check population quality through egg mass viability and virus incidence). The decision to start the NEPA process cannot wait until this stage is complete. Egg viability and virus incidence determinations require considerable laboratory examinations and can take several months to complete, yet they are very important in the final decision to go ahead with a treatment recommendation.

Level VIII, Checking Outbreak Boundaries and Assessing Population Quality

The sequential larval survey (Level III) should be used as much as possible to geographically delineate infestation boundaries. A check on these boundaries can be obtained through extensive pheromone trapping around the defined area. This will insure that areas of high population have not been missed. If new areas are found, early instar larval density estimates can be obtained the following spring.

It is also important at this time to assess the quality of the overwintering population through a virus incidence evaluation. This involves determining percent viable eggs, eggs per egg mass, and percent parasitism. Egg masses collected from a subsample of the population density plots (Level IV) should be used for this evaluation. Numbers of eggs per mass, virus incidence, and egg viability will be estimated from egg masses collected close to the time of hatch. Techniques for determining each of these are described in the 1974 Environmental Impact Statement for DFTM (Anonymous 1974).

Egg mass density estimates are not needed unless no other population density estimates have been obtained. If egg mass density estimates are required, two or three sample plots should be taken first to establish population variance and the appropriate sample sizes for the survey. The reason is no survey methods have been developed to estimate DFTM egg mass densities over large areas. Mason (1970) provides numbers of sample trees required to estimate egg populations at a single sample point. Four whole branches from the upper, middle, and lower crown in a 1:2:1 combination are used. Sample size is dependent upon population levels.

Summary

The intent in presenting these procedures is to illustrate the orderly flow of survey and evaluation techniques. More importantly, a treatment decision is the culmination of a series of evaluation steps. These steps constitute a process conducive to making a treatment decision early in the outbreak cycle before resource loss has occurred.

This document can serve as an organizational guide for scheduling survey activities. Both the resource manager and the survey entomologist must be aware of where information is leading. For example, classification of sequential larval plots as sub-outbreak indicates that additional surveys are to follow and may lead to a treatment recommendation.

As additional survey or sampling techniques are developed, the present procedures can be modified. It is important, however, that all evaluation procedures be used within the context of an on-going pest management strategy. Detection and evaluation procedures are best thought of as providing answers to pest management questions. The process outlined here attempts to identify the relevant questions and where solutions to those questions lead within a pest management strategy.

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